CAM MECHANISM OF A LENS BARREL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a cam mechanism of a lens barrel which includes a first ring member (e.g., a cam ring) and a second ring member (e.g., a lens frame) supporting a part of a lens system, wherein the first ring member is rotated to move the second ring member linearly along the optical axis of the lens system.

2. Description of the Related Art

In conventional zoom lenses (zoom lens barrels), it is often the case that a lens support ring which supports a part of a zoom lens system is linearly moved along the optical axis thereof by rotation of a cam ring which is driven to rotate. The cam ring includes a plurality of cam grooves which are formed on a peripheral surface of the cam ring to have the same reference cam diagrams, while the lens support ring that is linearly guided along the optical axis includes a corresponding plurality of cam followers which are engaged in the plurality of cam grooves of the cam ring, respectively. The plurality of cam grooves, which have the same reference cam diagrams, and the plurality of cam followers are generally arranged at equi-angular intervals of 120 degrees.

However, a substantial reduction in diameter of the cam ring of a zoom lens in order to miniaturize the cam ring causes adjacent cam grooves of the cam ring to be formed so as to intersect each other on the cam ring, which may cause each cam follower to come off the associated cam groove if the plurality of cam grooves and the plurality of cam followers are simply arranged at equi-angular intervals of 120 degrees.

In addition, there is a sufficient possibility of the relationship between the plurality of cam grooves and the plurality of cam followers being applied to a moving mechanism for moving a focusing lens group or any other optical element, not only to a power-varying lens group of a zoom lens optical system.

SUMMARY OF THE INVENTION

The present invention provides a cam mechanism of a lens barrel which includes a first ring member and a second ring member supporting a part of a lens system, wherein the first ring member is rotated to move the second ring member linearly along the optical axis of the lens system, and wherein there is no possibility of a plurality of cam followers which are formed on one of the first ring member and the second ring member coming off a corresponding plurality of cam grooves, having the same

reference cam diagrams which are formed on the other of the first ring member and the second ring member, even if adjacent cam grooves of the cam ring are formed to intersect each other.

According to an aspect of the present invention, a cam mechanism of a lens barrel is provided, including a first ring member driven to rotate about an optical axis; a second ring member which supports an optical element, and is linearly guided along the optical axis without rotating; a plurality of cam grooves having the same cam diagrams which are formed on one of the first ring member and the second ring member; and a plurality of cam followers formed on the other of the first ring member and the second ring member to be engaged in the plurality of cam grooves, respectively. At least two groove/follower groups, each of which includes a front groove/follower set and a rear groove/follower set which are positioned at different positions in the optical axis direction, are positioned at different positions in a circumferential direction, each of the front groove/follower set and the rear groove/follower set including a cam groove of the plurality of cam grooves and an associated cam follower of the plurality of cam followers. The cam grooves of one of the two groove/follower groups intersect the cam grooves of

another of the two groove/follower groups, respectively. At least one of the following two conditions (a) and (b) is satisfied: (a) a distance in the optical axis direction between the front groove/follower set and the rear groove/follower set of one of the two groove/follower groups is different from a distance in the optical axis between the front groove/follower set and the rear groove/follower set of another of the two groove/follower groups, and (b) a distance in the circumferential direction between two the front groove/follower sets of the two groove/follower groups is different from a distance in the circumferential direction between two the rear groove/follower sets of the two groove/follower groups. The term "groove/follower set (front groove/follower set or rear groove/follower set) means that the plurality of cam grooves are in a one-to-one correspondence with the plurality of cam followers, which are engaged in the plurality of cam grooves, respectively, and further means that the width and the depth of a cam groove correspond to the width and the depth of an associated cam follower, respectively. Accordingly, a discussion of the position and the contours of each cam groove (or each cam follower) logically corresponds a discussion of the position and the contours of the associated cam

follower (or the associated cam groove).

According to this cam mechanism, each cam follower can be prevented from coming off the associated cam groove regardless of how each cam groove intersects another cam groove(s).

The present invention can be embodied in theory if only there are two groove/follower groups at different positions in a circumferential direction; however, it is desirable that there are at least three groove/follower groups at different positions in a circumferential direction to hold the optical element (e.g., a lens group). According to this structure, the cam grooves (front and rear cam grooves) of one groove/follower group can be made to intersect the cam grooves (front and rear cam grooves) of another groove/follower group, respectively.

A. It is desirable for least one of the following two conditions (c) and (d) to be satisfied: (c) the front groove/follower sets of the three groove/follower groups are positioned at irregular intervals in the circumferential direction, and (d) the rear groove/follower sets of the three groove/follower groups are positioned at irregular intervals in the circumferential direction.

B. It is desirable for a distance in the optical

axis direction between the front groove/follower set and the rear groove/follower set of one of the three groove/follower groups is different from a distance in the optical axis direction between the front groove/follower set and the rear groove/follower set of another of the three groove/follower groups.

C. It is desirable for the cam groove of the front groove/follower set and the cam groove of the rear groove/follower set to be different in at least one of width and depth for at least one of the three groove/follower groups.

D. It is desirable for the width relationship between the cam groove of the front groove/follower set and the cam groove of the rear groove/follower set of one of the three groove/follower groups to be different from that between the cam groove of the front groove/follower set and the cam groove of the rear groove/follower set of another of the three groove/follower groups.

It is desirable for two cam grooves of the plurality of cam grooves which are adjacent in the circumferential direction to be different in at least one of width and depth.

The number of the plurality of cam grooves is determined according to the diameter of the lens barrel, the contours of the cam grooves and other factors. In

a particular lens barrel which has been developed in a company of the applicant of the present invention, it has been proved that the most practical number of the groove/follower sets (i.e., the sum of the number of the front groove/follower sets and the number of the rear groove/follower sets) is six (namely, the three groove/follower groups are arranged at different positions in the circumferential direction).

The optical element can be not only a lens group such as a power-varying lens group or a focusing lens group but also any other optical element such as an image pick-up device.

The lens system can be a zoom lens optical system.

It is desirable for the first ring member to be fitted on the second ring member to be positioned coaxial with the second ring member.

It is desirable for the plurality of cam grooves to be formed on an inner peripheral surface of the first ring member, and the plurality of cam followers to be formed on an outer peripheral surface of the second ring member.

It is desirable for the first ring member to include another plurality of cam grooves formed on an outer peripheral surface of the first ring member.

It is desirable for the first ring member to include

a spur gear which is formed on an outer peripheral surface of the first ring member in the vicinity of the rear end thereof to be engaged with a drive pinion.

It is desirable for teeth of the spur gear to be formed on the thread of a male helicoid formed on the outer peripheral surface of the first ring member.

It is desirable for the lens barrel to include a stationary barrel having a female helicoid formed on an inner peripheral surface of the stationary barrel. The male helicoid of the first ring member is engaged with the female helicoid of the stationary barrel.

It is desirable for the first ring member to rotate while moving along the optical axis when driven to rotate.

The present disclosure relates to subject matter contained in Japanese Patent Application Nos.2003-027341 and 2003-027342 (both filed on February 4, 2003) which are expressly incorporated herein by reference in their entireties.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described below in detail with reference to the accompanying drawings in which:

Figure 1 is a diagram showing reference moving paths

of zoom lens groups of a zoom lens system provided in an embodiment of a zoom lens barrel according to the present invention;

Figure 2 is an exploded perspective view in axial section of the zoom lens groups and lens support frames therefor;

Figure 3 is a longitudinal cross sectional view of the embodiment of the zoom lens barrel according to the present invention, showing an upper half of the zoom lens barrel from the optical axis thereof in a retracted state;

Figure 4 is a view similar to that of Figure 3, and shows an upper half of the zoom lens barrel from the optical axis thereof at the wide-angle extremity;

Figure 5 is a view similar to that of Figure 3, and shows a lower half of the zoom lens barrel from the optical axis thereof at the telephoto extremity;

Figure 6 is a transverse cross sectional view taken along VI-VI line shown in Figure 3;

Figure 7 is a transverse cross sectional view taken along VII-VII line shown in Figure 3;

Figure 8 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3;

Figure 9 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3;

Figure 10 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3, showing a first lens group moving ring and peripheral elements;

Figure 11 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3, showing a third lens group moving ring and peripheral elements;

Figure 12 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3, showing a second lens group moving ring and peripheral elements;

Figure 13 is a longitudinal view of a portion of the zoom lens barrel shown in Figure 3, showing a portion of the second lens group moving ring and peripheral elements;

Figure 14 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3, showing a stationary barrel, a pulse motor supported by the stationary barrel, and peripheral elements, seen from the rear side thereof;

Figure 15 is an exploded perspective view of a portion of the zoom lens barrel shown in Figure 3, showing the stationary barrel, a fourth lens group and peripheral elements;

Figure 16 is a developed view of a cam/helicoid ring, showing first cam grooves of the cam/helicoid ring for moving the first lens group and third cam grooves of the

cam/helicoid ring for moving an exterior ring;

Figure 17 is a developed view of the first lens group moving ring, the second lens group moving ring and the third lens group moving ring, showing linear guide mechanical linkages among these three moving rings;

Figure 18 is an enlarged view of a portion of the developed view shown in Figure 17;

Figure 19 is a developed view of the cam/helicoid ring and shows the contours of second cam grooves of the cam/helicoid ring for moving the second lens group, and associated cam followers of the second lens group moving ring, showing an embodiment of a cam mechanism of a zoom lens barrel;

Figure 20A is a diagrammatic developed view of second cam grooves of the cam/helicoid ring and associated cam followers of the second lens group moving ring, showing another embodiment of the cam mechanism in which two groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring;

Figure 20B is a view similar to that of Figure 20A, showing the embodiment of the cam mechanism shown in Figure 20A in a different state;

Figure 21A is a diagrammatic developed view of second cam grooves of the cam/helicoid ring and

associated cam followers of the second lens group moving ring, showing another embodiment of the cam mechanism in which two groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring;

Figure 21B is a view similar to that of Figure 21A, showing the embodiment of the cam mechanism shown in Figure 21A in a different state;

Figure 22 is a diagrammatic developed view of second cam grooves of the cam/helicoid ring and associated cam followers of the second lens group moving ring, showing another embodiment of the cam mechanism in which three groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring;

Figure 23 is a view similar to that of Figure 22, showing another embodiment of the cam mechanism in which three groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring;

Figure 24 is a view similar to that of Figure 22, showing another embodiment of the cam mechanism in which three groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring;

Figure 25A is a diagrammatic developed view of cam grooves and associated cam followers, showing a comparative example of the placement of the cam followers and the associated cam followers of the cam mechanism which is to be compared with those of a cam mechanism according to the present invention; and

Figure 25B is a view similar to that of Figure 25A, showing the comparative example shown in Figure 25A in a different state.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First of all, a zoom lens system (zoom lens optical system) provided in an embodiment of a zoom lens barrel of a camera according to the present invention will be hereinafter discussed with reference to Figures 1 through 5. The zoom lens system of the zoom lens barrel 10 is a vari-focal lens system consisting of four lens groups: a positive first lens group L1, a negative second lens group L2, a positive third lens group L3 and a positive fourth lens group L4, in that order from the object side (left side as viewed in Figure 3). The first through third lens groups L1, L2 and L3 are moved relative to one another along an optical axis O to vary the focal length of the zoom lens system and the fourth lens group L4 is moved along the optical axis O to make a slight focus

adjustment, i.e., to adjust a slight focus deviation caused by the variation of the focal length. During the operation of varying the focal length of the zoom lens system between wide angle and telephoto, the first lens group L1 and the third lens group L3 move along the optical axis while maintaining the distance therebetween. The fourth lens group L4 also serves as a focusing lens group. Figure 1 shows both moving paths of the first through fourth lens groups L1 through L4 during the zooming operation and moving paths for advancing/retracting operation. By definition, a vari-focal lens is one whose focal point slightly varies when varying the focal length, and a zoom lens is one whose focal point does not vary substantially when varying the focal length. However, the vari-focal lens system of the present invention is also hereinafter referred to as a zoom lens system.

The overall structure of the zoom lens barrel 10 will be hereinafter discussed with reference to Figures 1 through 19. The zoom lens barrel 10 is provided with a stationary barrel 11 which is fixed to a camera body (not shown). As shown in Figure 8, the stationary barrel 11 is provided on an inner peripheral surface thereof with a female helicoid 11a and a set of three linear guide grooves 11b which extend parallel to the optical axis O.

The zoom lens barrel 10 is provided inside the stationary barrel 11 with a cam/helicoid ring (cam ring) 12. As shown in Figure 9, the cam/helicoid ring 12 is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the cam/helicoid ring 12, with a male helicoid 12a which is engaged with the female helicoid 11a of the stationary barrel 11. The cam/helicoid ring 12 is provided on the thread of the male helicoid 12a with a spur gear 12b which is always engaged with a drive pinion 13 (see Figure 15). The drive pinion 13 is provided in a recessed portion 11c (see Figure 3) formed on an inner peripheral surface of the stationary barrel 11. The drive pinion 13 is supported by the stationary barrel 11 to be freely rotatable in the recessed portion 11c on an axis of the drive pinion 13. Accordingly, forward and reverse rotations of the drive pinion 13 cause the cam/helicoid ring 12 to move forward rearward along the optical axis O while rotating about the optical axis O due to the engagement of the drive pinion 13 with the spur gear 12b and the engagement of the female helicoid 11a with the male helicoid 12a. In the present embodiment of the zoom lens barrel 10, the cam/helicoid ring 12 is the only element thereof which rotates about the optical axis O.

The zoom lens barrel 10 is provided around the

cam/helicoid ring 12 with a linear guide ring 14. The linear guide ring 14 is provided, on an outer peripheral surface thereof at the rear end of the linear guide ring 14, with a set of three linear guide projections 14a which project radially outwards to be engaged in the set of three linear guide grooves 11b of the stationary barrel 11, respectively. The linear guide ring 14 is provided, on an inner peripheral surface thereof at the rear end of the linear guide ring 14, with a set of three bayonet lugs 14b (only one of them appears in Figures 1 through 4). The cam/helicoid ring 12 is provided, on an outer peripheral surface thereof immediately in front of the male helicoid 12a (the spur gear 12b), with a circumferential groove 12c in which the set of three bayonet lugs 14b are engaged to be rotatable about the optical axis O in the circumferential groove 12c. Accordingly, the linear guide ring 14 is linearly movable along the optical axis O together with the cam/helicoid ring 12 without rotating about the optical axis O.

The zoom lens barrel 10 is provided around the cam/helicoid ring 12 with a first lens group moving ring (first lens frame) 15 which supports the first lens group L1, and is further provided around the first lens group moving ring 15 with an exterior ring 16 serving as a light shield member. The zoom lens barrel 10 is provided

inside the cam/helicoid ring 12 with a second lens group moving ring (second lens frame) 17 which supports the second lens group L2. As shown in Figures 4, 9 and 16, the cam/helicoid ring 12 is provided on an outer peripheral surface thereof with a set of three first cam grooves C15 for moving the first lens group moving ring 15 and a set of three third cam grooves C16 for moving the exterior ring 16, and is further provided on an inner peripheral surface of the cam/helicoid ring 12 with a set of six second cam grooves C17 for moving the second lens group moving ring 17 (see Figure 19). The set of three first cam grooves C15 and the set of three third cam grooves C16 are slightly different in shape, and are apart from one another at predetermined intervals in a circumferential direction of the cam/helicoid ring 12. The set of six second cam grooves C17 have the same basic cam diagrams, and includes three front second cam grooves C17, and three rear second cam grooves C17 which are positioned behind the three front second cam grooves C17 in the optical-axis direction (vertical direction as viewed in Figure 19), respectively; the three front second cam grooves C17 are apart from one another in a circumferential direction of the cam/helicoid ring 12 while the three rear second cam grooves C17 are apart from one another in a circumferential direction of the

cam/helicoid ring 12. Each of the first lens group moving ring 15, the exterior ring 16 and the second lens group moving ring 17 is linearly guided along the optical axis O. A rotation of the cam/helicoid ring 12 causes the first lens group moving ring 15, the exterior ring 16 and the second lens group moving ring 17 to move along the optical axis O in accordance with the contours of the set of three first cam grooves C15, the set of three third cam grooves C16 and the set of six second cam grooves C17, respectively.

Linear guide mechanical linkages among the first lens group moving ring 15, the exterior ring 16 and the second lens group moving ring 17 will be discussed hereinafter. As shown in Figures 4 and 5, the first lens group moving ring 15 is provided with an outer ring portion 15X, an inner ring portion 15Y and a flange wall 15Z by which the front end of the outer ring portion 15X and the front end of the inner ring portion 15Y are connected to have a substantially U-shaped cross section. The cam/helicoid ring 12 is positioned between the outer ring portion 15X and the inner ring portion 15Y. Three cam followers 15a which are respectively engaged in the set of three first cam grooves C15 are fixed to the outer ring portion 15X in the vicinity of the rear end thereof. The zoom lens barrel 10 is provided with a first lens

group support frame 24 which supports the first lens group L1. As shown in Figures 8 and 9, the first lens group support frame 24 is fixed to the inner ring portion 15Y at the front end thereof through a male thread portion and a female thread portion which are formed on an outer peripheral surface of the first lens group support frame 24 and an inner peripheral surface of the inner ring portion 15Y, respectively (see Figure 10). The first lens group support frame 24 can be rotated relative to the first lens group moving ring 15 to adjust the position of the first lens group support frame 24 along the optical axis O relative to the first lens group moving ring 15 to carry out a zooming adjustment (which is an adjustment operation which is carried out in a manufacturing process of the zoom lens barrel if necessary).

The linear guide ring 14, which is linearly guided along the optical axis O by the stationary barrel 11, is provided, on an inner peripheral surface thereof at approximately equi-angular intervals (intervals of approximately 120 degrees), with a set of three linear guide grooves 14c (only one of them appears in Figure 9), while the outer ring portion 15X of the first lens group moving ring 15 is provided at the rear end thereof with a set of three linear guide projections 15b (see Figure 10) which project radially outwards to be engaged in the

set of three linear guide grooves 14c, respectively. The outer ring portion 15X is provided with a set of three assembly slots 15c (see Figures 10 and 16), and is further provided at the rear ends of the set of three assembly slots 15c with a set of linear guide slots 15d which are communicatively connected with the set of three assembly slots 15c and are smaller in width than the set of three assembly slots 15c, respectively. Three linear guide keys 16a which are fixed to the exterior ring 16 which is positioned between the outer ring portion 15X and the linear guide ring 14 are engaged in the set of linear guide slots 15d, respectively. The maximum relative moving distance between the first lens group moving ring 15 and the exterior ring 16 along the optical axis O (the difference in shape between the set of three first cam grooves C15 and the set of three third cam grooves C16) is only a slight distance, and the length of each linear guide slot 15d in the optical-axis direction is correspondingly short. A set of three cam followers 16b which are engaged in the set of three third cam grooves C16 are fixed to the set of three linear guide keys 16a, respectively (see Figures 7 and 9).

The zoom lens barrel 10 is provided between the first lens group moving ring 15 and the exterior ring 16 with a compression coil spring 19 (see Figures 3 through

5). The compression coil spring 19 biases the first lens group moving ring 15 rearward to remove backlash between the set of three first cam grooves C15 and the set of three cam followers 15a, and at the same time, biases the exterior ring 16 forward to remove backlash between the set of three third cam grooves C16 and the set of three cam followers 16b.

As shown in Figure 16, the set of three first cam grooves C15 and the set of three third cam grooves C16 are shaped slightly different from each other in their respective retracting ranges, as compared with their respective photographing ranges (zooming ranges), so that the exterior ring 16 advances from the photographing position thereof relative to the first lens group moving ring 15 to prevent barrier blades of a lens barrier unit 30 (see Figure 8) and the first lens group L1 from interfering with each other when the zoom lens barrel 10 is fully retracted as shown in Figure 3. More specifically, as shown in Figure 16, the shapes of the first cam grooves C15 and the third cam grooves C16 are determined so that the distance Q in the optical axis direction between the first cam grooves C15 and the third cam grooves C16 in the preparation ranges (i.e., the range between the retracted position and the position at which the lens barrier unit 30 is fully open) is longer

than that of the zoom ranges (i.e., the range between the wide-angle extremity and the telephoto extremity). Namely, throughout the entirety of the preparation ranges the distance Q = Q1, however, the distance Q gradually reduces from a position OP2 at a predetermined distance from a fully opened position OP1 of the lens barrier unit 30 (i.e., from a position whereby the first lens group L1 and the lens barrier unit 30 do not interfere with each other), so that the distance Q = Q2 (< Q1) at the wide-angle extremity, and the distance Q = Q2 in the entirety of the zoom ranges. It can be seen that a clearance c1 (see Figure 3) between the flange wall 15Z of the first lens group moving ring 15 and a flange wall 16f of the exterior ring 16 when the zoom lens barrel 10 is in the retracted position as shown in Figure 3 is greater than that when the zoom lens barrel 10 is in a ready-to-photograph position as shown in Figure 4 or 5. In other words, when the zoom lens barrel 10 is in a ready-to-photograph position as shown in Figure 4 or 5, the flange wall 15Z of the first lens group moving ring 15 and the flange wall 16f of the exterior ring 16 are positioned closely to each other to prevent vignetting which may be caused by the barrier unit 30 from occurring. The lens barrier unit 30 is supported by the exterior ring 16 at the front end thereof. The zoom lens barrel 10 is

provided, immediately behind the lens barrel unit 30 between the lens barrier unit 30 and the flange wall 16f of the exterior ring 16, with a barrier opening/closing ring 31 (see Figure 9). Rotating the barrier opening/closing ring 31 by rotation of the cam/helicoid ring 12 causes the barrier blades of the lens barrier unit 30 to open and shut. The mechanism for opening and closing the barrier blades using a barrier opening/closing ring such as the barrier opening/closing ring 31 is known in the art. Note that in the illustrated embodiment, although the shapes of the first cam grooves C15 and the third cam grooves C16 are determined so that the distance Q (i.e., Q2) is constant (unchanging) over the entire zoom range, the distance Q (i.e., Q2) can be determined so as to change in accordance with the focal length. Furthermore, the distance Q2 over the zoom range can be determined so as to be greater than the distance Q1 over the preparation range.

The front end of each third cam groove C16 is open on a front end surface of the cam/helicoid ring 12 to be formed as an open end C16a (see Figure 16) through which the associated cam follower 16b of the exterior ring 16 is inserted into the third cam groove C16. Likewise, the front end of each first cam groove C15 is open on a front end surface of the cam/helicoid ring 12 to be formed as

an open end C15a (see Figure 16) through which the associated cam follower 15a of the first lens group moving ring 15 is inserted into the first cam groove C15.

The inner ring portion 15Y of the first lens group moving ring 15 is provided on an inner peripheral surface thereof with a set of three linear guide projections 15f which are elongated in a direction parallel to the optical axis O, while the second lens group moving ring 17 is provided with a set of three linear guide slots (linear guide through-slots) 17a which are elongated in a direction parallel to the optical axis O to be engaged with the set of three linear guide projections 15f to be freely slidable relative thereto along the optical axis O (see Figures 6, 7 and 17). Each linear guide projection 15f is provided along a substantially center thereof with a hanging groove 15e which is elongated in a direction parallel to the optical axis O and which has a substantially T-shaped cross section as shown in Figure 6. The three linear guide projections 15f and the three linear guide slots 17a constitute a first linear guide mechanism. The rear end of each hanging groove 15e is closed (see Figures 17 and 18). The second lens group moving ring 17 is provided on an outer peripheral surface thereof with six cam followers 17c which are engaged in the set of six second cam grooves C17 of the cam/helicoid

ring 12, respectively.

The zoom lens barrel 10 is provided inside the second lens group moving ring 17 with a third lens group moving ring (third lens frame) 18 which supports the third lens group L3. The third lens group moving ring 18 is provided on an outer peripheral surface thereof with a set of three linear guide projections 18a which are elongated in a direction parallel to the optical axis O to be engaged in the set of three linear guide slots 17a of the second lens group moving ring 17 to be freely slidable relative thereto along the optical axis O, respectively. The third lens group moving ring 18 is provided on a center of each linear guide projection 18a at the front end thereof with a linear moving key (stop projection) 18b (see Figures 11, 17 and 18) which has a substantially T-shaped cross section to be engaged in the associated hanging groove 15e. The three linear guide projections 15f, the three hanging groove 15e and the three linear moving keys 18b constitute a second linear guide mechanism. Furthermore, the three linear guide slots 17a and the three linear guide projections 18a constitute a third linear guide mechanism. As shown in Figure 11, the zoom lens barrel 10 is provided with a shutter unit 20 which is inserted into the third lens group moving ring 18 to be positioned in front of the

third lens group L3. The shutter unit 20 is fixed to the third lens group moving ring 18 by a fixing ring 20a. The zoom lens barrel 10 is provided between the third lens group moving ring 18 (the fixing ring 20a) and the second lens group moving ring 17 with a compression coil spring 21 which continuously biases the third lens group moving ring 18 rearwards relative to the second lens group moving ring 17. The rear limit of this rearward movement of the third lens group moving ring 18 relative to the second lens group moving ring 17 is determined by the three linear moving keys 18b contacting the closed rear ends of the three hanging grooves 15e, respectively. Namely, when the zoom lens barrel 10 is in a ready-to-photograph position, each linear moving key 18b remains in contact with the rear end of the associated hanging groove 15e of the first lens group moving ring 15 to keep the distance between the first lens group L1 and the third lens group L3 constant. When the zoom lens barrel 10 changes from a ready-to-photograph state to the retracted state shown in Figure 3, a further rearward movement of the first lens group L1 in accordance with contours of the set of three first cam grooves C15, after the third lens group L3 (the third lens group moving ring 18) has reached the mechanical rear moving limit thereof, causes the first lens group L1 to approach the third lens

group L3 while compressing the compression coil spring 21 (see Figure 1). Each linear moving key 18b is formed so that the radially outer end thereof bulges to be prevented from coming off the associated hanging groove 15e.

Although a biasing force of the compression coil spring 21 can be applied directly to the second lens group moving ring 17 (i.e., although the second lens group L2 can be fixed to the second lens group moving ring 17), the second lens group L2 is made to be capable of moving rearward relative to the second lens group moving ring 17 for the purpose of further reduction in length of the zoom lens barrel 10 in the retracted state thereof in the present embodiment of the zoom lens barrel. Figures 12 and 13 show this structure for the further reduction in length of the zoom lens barrel 10. The second lens group moving ring 17 is provided at the front end thereof with a cylindrical portion 17e having an inner flange 17d. The zoom lens barrel 10 is provided inside the second lens group moving ring 17 with an intermediate ring 25. The intermediate ring 25 is provided at the front end thereof with a flange portion 25a which is fitted in the cylindrical portion 17e to be freely slidable on the cylindrical portion 17e in the optical axis direction. An end portion of the compression coil spring 21 abuts

against the flange portion 25a, so that the flange portion 25a presses against the inner flange 17d due to the resiliency of the compression coil spring 21. As clearly shown in Figure 12, the second lens group moving ring 17 is provided, on an inner peripheral surface of the cylindrical portion 17e at substantially equi-angular intervals, with a set of three linear guide grooves 17f which are elongated in a direction parallel to said optical axis O, while the intermediate ring 25 is provided on an outer edge of said flange portion 25a with a corresponding set of three linear guide projections 25d (only two of them appear in figure 12) which are engaged in the set of three linear guide grooves 17f, respectively, to guide said intermediate ring 25 linearly along the optical axis O without rotating said intermediate ring 25 relative to said second lens group moving ring 17. The zoom lens barrel L2 is provided inside the second lens group moving ring 17 with a second lens group support frame 26 to which the second lens group L2 is fixed. The second lens group support frame 26 is screwed into the intermediate ring 25. Specifically, a male thread 26b formed on an outer peripheral surface of the second lens group support frame 26 is engaged with a female thread 25e formed on an inner peripheral surface of the intermediate ring 25. Accordingly, the position

of the second lens group L2 in the optical axis direction relative to the intermediate ring 25, which is prevented from rotating about the optical axis O, can be adjusted (zooming adjustment) by rotating the second lens group support frame 26 relative to the intermediate ring 25. After this adjustment, the second lens group support frame 26 can be permanently fixed to the intermediate ring 25 by putting drops of an adhesive agent into a radial through hole 25b formed on the intermediate ring 25. The second lens group support frame 26 is provided on an outer peripheral surface thereof with an outer flange 26a, and a clearance C2 (see Figure 13) for the zooming adjustment exits between a front end surface of the inner flange 17d and the outer flange 26a. The compression coil spring 21 biases the intermediate ring 25 forward, and the intermediate ring 25 is held at a position where the flange portion 25a contacts with the inner flange 17d when the zoom lens barrel 10 is in a ready-to-photograph state. Namely, on the one hand, the position of the second lens group L2 is controlled by the set of six second cam grooves C17 when the zoom lens barrel 10 is in a ready-to-photograph state; on the other hand, the second lens group support frame 26 is pushed rearward mechanically by the rear end of the first lens group support frame 24 to thereby move the outer flange

26a of the second lens group support frame 26 rearward to a point where the outer flange 26a contacts with the inner flange 17d when the zoom lens barrel 10 is retracted to the retracted position thereof. This reduces the length of the zoom lens barrel 10 by a length corresponding to the clearance C2.

The zoom lens barrel 10 is provided immediately behind the intermediate ring 25 with a light shield ring 27 which is supported by the intermediate ring 25. As shown in Figure 12, the light shield ring 27 is provided with a ring portion 27a and a set of three leg portions 27b which extend forward from the ring portion 27a at intervals of approximately 120 degrees. Each leg portion 27b is provided at the front end thereof with a hook portion 27c which is formed by bending the tip of the leg portion 27b radially outwards. The intermediate ring 25 is provided on an outer peripheral surface thereof with a set of three engaging holes 25c with which the hook portions 27c of the set of three leg portions 27b are engaged, respectively (see Figure 12). The zoom lens barrel 10 is provided between the light shield ring 27 and the second lens group support frame 26 with a compression coil spring 28 having a substantially truncated conical shape which continuously biases the light shield ring 27 rearwards. When the zoom lens

barrel 10 is retracted toward the retracted position, the light shield ring 27 approaches the second lens group support frame 26 while compressing the compression coil spring 28 after reaching the rear moving limit of the light shield ring 27. The lengths of the set of three engaging holes 25c in the optical axis direction are determined to allow the ring portion 27a to come into contact with the second lens group support frame 26.

The compression coil spring 28 also serves as a device for removing backlash between the intermediate ring 25 and the second lens group support frame 26 when the second lens group support frame 26 is rotated relative to the intermediate ring 25 for the aforementioned zooming adjustment. The zooming adjustment is performed by rotating the second lens group support frame 26 relative to the intermediate ring 25 to adjust the position of the second lens group L2 in the optical axis direction relative to the intermediate ring 25 while viewing the position of an object image. This zooming adjustment can be performed with precision with backlash between the intermediate ring 25 and the second lens group support frame 26 being removed by the compression coil spring 28.

The zoom lens barrel 10 is provided behind the third lens group moving ring 18 with a fourth lens group support

frame 22 to which the fourth lens group L4 is fixed. As described above, the fourth lens group L4 is moved to make a slight focus adjustment to the vari-focal lens system to adjust a slight focal deviation thereof while the first through third lens groups L1 , L2 and L3 are moved relative to one another to vary the focal length of the zoom lens system, and is also moved as a focusing lens group. The fourth lens group L4 is moved along the optical axis O by rotation of a pulse motor 23 (see Figures 5 and 14). The pulse motor 23 is provided with a rotary screw shaft 23a. A nut member 23b is screwed on the rotary screw shaft 23a to be prevented from rotating relative to the stationary barrel 11. The nut member 23b is continuously biased by an extension coil spring S in a direction to contact with a leg portion 22a which projects radially outwards from the fourth lens group support frame 22 (see Figures 5 and 15). The fourth lens group support frame 22 is prevented from rotating by guide bars 22b, which extend in direction parallel to the optical axis direction, which are slidably engaged with radial projecting followers 22c which extend radially outwards from the fourth lens group support frame 22 (see Figures 2 and 15). Accordingly, rotations of the pulse motor 23 forward and reverse cause the fourth lens group support frame 22 (the fourth lens

group L4) to move forward and rearward along the optical axis O, respectively. Rotations of the pulse motor 23 are controlled in accordance with information on focal length and/or information on object distance.

Accordingly, in the above described embodiment of the zoom lens barrel, rotating the cam/helicoid ring 12 by rotation of the drive pinion 13 causes the first lens group moving ring 15, the exterior ring 16 and the second lens group moving ring 17 to move along the optical axis O in accordance with contours of the set of three first cam grooves C15, the set of three third cam grooves C16 and the set of six second cam grooves C17, respectively. When the first lens group moving ring 15 moves forward from the retracted position, firstly the three linear moving keys 18b contact the rear ends of the three hanging grooves 15e, respectively, and subsequently the third lens group moving ring 18 moves together with the first lens group moving ring 15 with the three linear moving key 18b remaining in contact with the rear ends of the three hanging grooves 15e, respectively. The position of the fourth lens group L4 is controlled by the pulse motor 23, whose rotations are controlled in accordance with information on focal length, to make a slight focus adjustment to the vari-focal lens system to adjust a slight focal deviation thereof. As a result, reference

moving paths as shown in Figure 1 for performing a zooming operation are obtained. Rotations of the pulse motor 23 are also controlled in accordance with information on object distance to perform a focusing operation.

In the above described embodiment of the zoom lens barrel, the six second cam grooves C17 for moving the second lens group moving ring 17 are formed on an inner peripheral surface of the cam/helicoid ring (cam ring/first ring member) 12. The six second cam grooves C17 have the same reference cam diagrams, and include three front second cam grooves C17 (C17f1, C17f2 and C17f3) and three rear second cam grooves C17 (C17r1, C17r2 and C17r3), wherein the three front second cam grooves C17 and the three rear second cam grooves C17 are apart from each other in the optical axis direction (vertical direction as viewed in Figure 19). Furthermore, the three front second cam grooves C17 are positioned at predetermined intervals in a circumferential direction of the cam/helicoid ring 12 while the three rear cam grooves C17 are arranged at predetermined intervals in the circumferential direction of the cam/helicoid ring 12 (see Figure 19). The second lens group moving ring 17 is linearly guided along the optical axis O to move linearly along the optical axis O in accordance with contours of the six

second cam grooves C17 when the cam/helicoid ring 12 rotates. A feature of the present invention resides in the configuration of the six second cam grooves C17 on the second lens group moving ring 17. The six second cam grooves C17 are in a one-to-one correspondence with the six cam followers 17c, which are engaged in the six second cam grooves C17, respectively, while the width and the depth of each cam groove C17 correspond to the width and the depth of the associated cam follower 17c, respectively. Accordingly, in the following descriptions, a discussion of the position and the contours of each cam groove C17 (or each cam follower 17c) logically corresponds a discussion of the position and the contours of the associated cam follower 17c (or the associated cam groove C17).

Specifically, the above described embodiment of the cam mechanism composed of the six cam grooves C17 and the six cam followers 17c has the following six features (A) through (F).

(A) Three groove/follower groups (each group of which consists of two cam grooves C17 and the associated two cam followers 17c) are arranged at three positions in the circumferential direction of the cam/helicoid ring 12, while each groove/follower group includes a set of two cam grooves (front and rear cam grooves) C17 which

are apart from each other in the axial direction of the cam/helicoid ring 12. Specifically, the three groove/follower groups include a first set of two cam grooves C17 (C17f1 and C17r1) which are apart from each other in the axial direction of the cam/helicoid ring 12, a second set of two cam grooves C17 (C17f2 and C17r2) which are apart from each other in the axial direction of the cam/helicoid ring 12, and a third set of two cam grooves C17 (C17f3 and C17r3) which are apart from each other in the axial direction of the cam/helicoid ring 12, respectively. Accordingly, six cam grooves C17 in total are formed on the cam/helicoid ring 12.

(B) The six cam grooves C17 can also be classified into two groups which are apart from each other in the optical axis direction: a front cam-groove group consisting of the three cam grooves C17f1, C17f2 and C17f3, and a rear cam-groove group consisting of the three cam grooves C17r1, C17r2 and C17r3.

(C) Each of the front and rear cam grooves C17 of each groove/follower group intersects all the other cam grooves C17 of the remaining two groove/follower groups. For instance, each of the front and rear cam grooves C17f1 and C17r1 of the first set of two cam grooves C17 intersect all the other four cam grooves C17: the cam grooves C17f2 and C17r2 of the second set of two cam

grooves C17 and the cam grooves C17f3 and C17r3 of the third set of two cam grooves C17.

(D) The three cam grooves C17f1, C17f2 and C17f3 of the front cam-groove group are arranged in the circumferential direction of the cam/helicoid ring 12 at irregular intervals, while the three cam grooves C17r1, C17r2 and C17r3 of the rear cam-groove group are arranged in the circumferential direction of the cam/helicoid ring 12 at irregular intervals. Namely, intervals (angles) $\theta 1$, $\theta 2$ and $\theta 3$ among the three cam followers 17c (17cf1, 17cf2 and 17cf3) of the front cam-follower group in the circumferential direction of the cam/helicoid ring 12 are different from one another, while intervals (angles) $\gamma 1$, $\gamma 2$ and $\gamma 3$ among the three cam followers 17c (17cr1, 17cr2 and 17cr3) of the rear cam-follower group in the circumferential direction of the cam/helicoid ring 12 are different from one another. In addition, the positions of the front and rear cam grooves C17f1 and C17r1 in the circumferential direction of the cam/helicoid ring 12 are the same, whereas the positions of the front and rear cam grooves C17f2 and C17r2 in the circumferential direction of the cam/helicoid ring 12 are mutually different while the positions of the front and rear cam grooves C17f3 and C17r3 in the circumferential direction of the cam/helicoid ring 12

are mutually different.

(E) A distance d1 between the first set of two cam grooves C17f1 and C17r1 in the optical axis direction, a distance d2 between the second set of two cam grooves C17f2 and C17r2 in the optical axis direction, and a distance d3 between the third set of two cam grooves C17f3 and C17r3 are different from one another.

(F) The widths of the first set of two cam grooves C17f1 and C17r1 are mutually different, the widths of the second set of two cam grooves C17f2 and C17r2 are mutually different, and the widths of the third set of two cam grooves C17f3 and C17r3 are mutually different.

The above described embodiment of the cam mechanism having the above six features (A) through (F) is a desirable embodiment for preventing each second cam follower 17f from coming off the associated second cam groove C17 in the above described arrangement wherein adjacent cam grooves of the cam ring (12) which have the same reference cam diagrams intersect each other for the purpose of reducing the diameter of the cam ring. However, as mentioned above, prevention of each cam follower (17c) from coming off the associated cam groove (C17) at an intersection between this cam groove (C17) and another cam groove (C17) can be accomplished as mentioned above in a cam mechanism of a lens barrel

wherein at least two groove/follower groups (each of which consists of a front groove/follower set and a rear groove/follower set which are positioned at different positions in an optical axis direction) are positioned at different positions in a circumferential direction, each of the front groove/follower set and the rear groove/follower set consisting of a cam groove of the plurality of cam grooves and an associated cam follower of the plurality of cam followers, wherein the cam grooves of one of the two groove/follower groups intersect the cam grooves of another of the two groove/follower groups, respectively, and wherein at least one of the following two conditions (A) and (B) is satisfied:

(A) a distance (d1, d2 or d3) in the optical axis direction between the front groove/follower set and the rear groove/follower set of one of the two groove/follower groups in the optical axis direction is different from that between the front groove/follower set and the rear groove/follower set of another of the two groove/follower groups, and

(B) a distance in the circumferential direction between the two front groove/follower sets of the two groove/follower groups is different from that between the two rear groove/follower sets of said two

groove/follower groups.

Figures 20A and 20B show another embodiment of the cam mechanism in which two groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring 12, wherein the distance in the optical axis direction between the front groove/follower set and the rear groove/follower set of one of the two groove/follower groups in the optical axis direction is different from that between the front groove/follower set and the rear groove/follower set of another of the two groove/follower groups. Specifically, a distance α in the circumferential direction of the cam/helicoid ring 12 between the front cam groove (C17f1) of the first set of two cam grooves C17 and the front cam groove (C17f2) of the second set of two cam grooves C17 is identical to a distance β in the circumferential direction of the cam/helicoid ring 12 between the rear cam groove (C17r1) of the first set of two cam grooves C17 and the rear cam groove (C17r2) of the second set of two cam grooves C17, and a distance A in the optical axis direction between the front and rear cam grooves (C17f1 and C17r1) of the first set of two cam grooves C17 is different from a distance B in the optical axis direction between the front and rear cam grooves (C17f2 and C17r2) of the second set of two cam grooves

C17.

Figures 21A and 21B show another embodiment of the cam mechanism in which two groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring 12, wherein the distance in the circumferential direction between the two front groove/follower sets of the two groove/follower groups is different from that between the two rear groove/follower sets of the two groove/follower groups, in contrast to the embodiment shown in Figures 20A and 20B. Specifically, the distance A between the front and rear cam grooves (C17f1 and C17r1) of the first set of two cam grooves C17 is identical to the distance B between the front and rear cam grooves (C17f2 and C17r2) of the second set of two cam grooves C17, while the distance α between the front cam groove (C17f1) of the first set of two cam grooves C17 and the front cam groove (C17f2) of the second set of two cam grooves C17 is different from the distance β between the rear cam groove (C17r1) of the first set of two cam grooves C17 and the rear cam groove (C17r2) of the second set of two cam grooves C17.

The two cam followers (front and rear cam followers) of each groove/follower group are not simultaneously positioned at associated two intersections of cam

grooves C17, respectively, as shown in each of the above two embodiments shown in Figures 20A through 21B. This prevents each cam groove C17 from coming off the associated cam groove 17c.

Figure 22 shows another embodiment of the cam mechanism in which three groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring, wherein the distance between the front and rear cam grooves (C17f1 and C17r1) of the first set of two cam grooves C17, the distance between the front and rear cam grooves (C17f2 and C17r2) of the second set of two cam grooves C17 and the distance between the front and rear cam grooves (C17f3 and C17r3) of the third set of two cam grooves C17 are all the same, and wherein intervals (angles) among the three cam followers 17c (17cf1, 17cf2 and 17cf3) of the front cam-follower group in the circumferential direction of the cam/helicoid ring 12 are irregular intervals (specifically, intervals of 116 degrees, 116 degrees and 128 degrees) while intervals (angles) among the three cam followers 17c (17cr1, 17cr2 and 17cr3) of the rear cam-follower group in the circumferential direction of the cam/helicoid ring 12 are regular intervals (specifically, intervals of 120 degrees).

In each of all the above described embodiments, each

cam second follower 17c can be prevented from coming off the associated second cam groove C17 more securely if the cam mechanism adopts at least one of the following four conditions (A) through (D).

(A) At least one of the following two conditions (1) and (2) is satisfied: (1) the front groove/follower sets of the three groove/follower groups are positioned at irregular intervals in the circumferential direction, and (2) the rear groove/follower sets of the three groove/follower groups are positioned at irregular intervals in the circumferential direction.

(B) A distance in the optical axis direction between the front groove/follower set and the rear groove/follower set of one of the three groove/follower groups in the optical axis direction is different from that between the front groove/follower set and the rear groove/follower set of another of the three groove/follower groups.

(C) The cam groove of the front groove/follower set and the cam groove of the rear groove/follower set are different in at least one of width and depth for at least one of the three groove/follower groups. Similar to making the width of the cam groove of the front groove/follower set and the width of the cam groove of the rear groove/follower set different from each other,

making the depth of the cam groove of the front groove/follower set and the depth of the cam groove of the rear groove/follower set different from each other is effective at preventing each cam follower from coming off the associated cam groove. However, making the depth of the cam groove of the front groove/follower set and the depth of the cam groove of the rear groove/follower set different from each other (e.g., making the depth of one cam groove C17 greater than the depth of another cam groove C17) is disadvantageous to a reduction in diameter of the lens barrel.

(D) The width relationship between the cam groove of the front groove/follower set and the cam groove of the rear groove/follower set of one of the three groove/follower groups is different from that between the cam groove of the front groove/follower set and the cam groove of the rear groove/follower set of another of the three groove/follower groups.

The arrangement of the six cam grooves (C17) can be determined depending on which of these four conditions (A) through (D)is to be adopted.

Figure 23 shows another embodiment of the cam mechanism in which the three cam grooves C17f1, C17f2 and C17f3 of the front cam-groove group are positioned at regular intervals (intervals of 120 degrees) in the

circumferential direction of the cam/helicoid ring 12, and also the cam grooves C17r1, C17r2 and C17r3 of the rear cam-groove group are positioned at regular intervals (intervals of 120 degrees) in the circumferential direction of the cam/helicoid ring 12. In addition, the distance between the cam grooves C17f1 and C17r1 of the first groove/follower group in the optical axis direction, the distance between the cam grooves C17f2 and C17r2 of the second groove/follower group in the optical axis direction and the distance between the cam grooves C17f3 and C17r3 of the third groove/follower group in the optical axis direction are mutually different.

Figure 24 shows another embodiment of the cam mechanism in which the three cam grooves C17f1, C17f2 and C17f3 of the front cam-groove group are positioned at regular intervals (intervals of 120 degrees) in the circumferential direction of the cam/helicoid ring 12, and also the cam grooves C17r1, C17r2 and C17r3 of the rear cam-groove group are positioned at regular intervals (intervals of 120 degrees) in the circumferential direction of the cam/helicoid ring 12. In addition, the distance between the cam grooves C17f1 and C17r1 of the first groove/follower group in the optical axis direction, the distance between the cam

grooves C17f2 and C17r2 of the second groove/follower group in the optical axis direction and the distance between the cam grooves C17f3 and C17r3 of the third groove/follower group in the optical axis direction are mutually different. Additionally, the widths of the cam grooves C17f1 and C17r1 are different from each other, the widths of the cam grooves C17f2 and C17r2 are different from each other, and the widths of the cam grooves C17f3 and C17r3 are different from each other. Furthermore, the width of the front cam groove C17f2 of the second groove/follower group is smaller than the width of the rear cam groove C17r2 of the second groove/follower group while the width of the front cam groove C17f3 of the third groove/follower group is smaller than the width of the rear cam groove C17r3 of the third groove/follower group, whereas the width of the front cam groove C17f3 of the third groove/follower group is greater than the width of the rear cam groove C17r3 of the third groove/follower group. Namely, the width relationship between the front and rear cam grooves in one of the three groove/follower groups is opposite to the width relationship between the front and rear cam grooves in either one of the remaining two groove/follower groups.

Figures 25A and 25B show a comparative example of

the cam mechanism, wherein two groove/follower groups are positioned at different positions in the circumferential direction of the cam/helicoid ring 12, wherein the distance in the optical axis direction between the front groove/follower set and the rear groove/follower set of one of the two groove/follower groups in the optical axis direction is identical to that between the front groove/follower set and the rear groove/follower set of the other groove/follower group, and wherein the distance in the circumferential direction between the two front groove/follower sets of the two groove/follower groups is identical to that between the two rear groove/follower sets of the two groove/follower groups. In this comparative example, even if the positions of the front groove/follower set and the rear groove/follower set are shifted relative to each other in the circumferential direction of the cam/helicoid ring 12, the two cam followers of each groove/follower group (front and rear cam followers C17f1 and C17r1, or C17f2 and C17r2) are simultaneously positioned at the intersection of the two cam grooves C17f1 and C17f2 and the intersection of the two cam grooves C17r1 and C17r2, respectively. This may cause each cam groove C17 to come off the associated cam groove 17c.

With the above described structures for preventing each cam follower 17c which is engaged in the associated cam groove C17 from entering another cam groove C17 accidentally at an intersection between these two cam grooves, it is possible to design a zoom lens barrel including a cam ring, on which cam grooves intersecting each other are formed, wherein each cam groove C17 can be made sufficiently long within the area of the inner peripheral surface of the cam/helicoid ring 12. Accordingly, the angle of inclination of each cam groove C17 can be made gentle, which makes it possible to achieve a reduction in diameter of the zoom lens barrel 10 and a smooth zooming operation.

The zoom lens barrel 10 which has been discussed above with reference to Figures 1 through 19 is just an example to which a cam mechanism devised according to the present invention is applied. The present invention can be applied not only to a zoom lens barrel such as the above described zoom lens barrel 10, but also to any other zoom lens barrel including a cam ring and a lens support ring, regardless of whether the cam ring includes a helicoid such as the male helicoid 12a of the cam/helicoid ring 12.

Although a plurality of cam grooves and a corresponding plurality of cam followers are formed on

the cam/helicoid ring 12 and the second lens group moving ring 17, respectively, in the above illustrated embodiment of the zoom lens barrel, it is obvious that the plurality of cam grooves and the corresponding plurality of cam followers can be formed on a ring member corresponding to the cam/helicoid ring 12 and another ring member corresponding to the second lens group moving ring 17, respectively.

Obvious changes may be made in the specific embodiments of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.